

# AN OVERVIEW OF NETWORKED SIMULATION TECHNOLOGY FROM THE WARFIGHTER TRAINING RESEARCH DIVISION PERSPECTIVE

## Abstract

This paper will describe simulation networking technology from the perspective of the Air Force Research Laboratory, Warfighter Training Research Division. The Division has been intimately involved in realtime networked simulation since it first demonstrated as being possible. A brief history of networked simulation will be presented to include the Division's extensive contributions followed by details of ongoing efforts concerning the use of modern network protocols. The Division first demonstrated 'long haul' networking in Oct 79. The 80's concept of Simulator Network (SIMNET), the Army's large scale simulation solution for networked ground vehicle training, was conceived by Division personnel. The Division was the first to demonstrate the 90's concept of Distributed Mission Training (DMT). The Apr 97 DMT demonstration will be described in detail. Current efforts involve the exploitation of Distributed Interactive Simulation (DIS) networking protocols for local and long haul multi-ship training research. The advantages and shortfalls of the High Level Architecture (HLA) are also being investigated. A brief definition of DIS and HLA will include the pros and cons of using each. Recommendations will be provided for newcomers, military and civil, to this technical subject area on which protocol(s) might best meet specific requirements.

## Introduction

This paper is written as a result of discussions held during the Networking Symposium of the July 2002 IMAGE Conference. At the symposium, it was pointed out that there are many relative newcomers to the field of simulator networking, especially from commercial aircraft simulation. The collective attendees believed that it would be good to present a paper covering the evolution of simulator networking and an overview of the two main realtime formats, Distributed Interactive Simulation (DIS) and High Level Architecture (HLA), and the advantages and disadvantages of using each for various types of simulation tasks. The Air Force Research Laboratory Warfighter Training Research Division has a unique perspective on simulation networking, having been involved since the very beginning, and continues to

define and expand the envelope for high-end simulation networking. This paper will describe simulator networking mostly, fortunately or unfortunately due to where the authors are employed, as viewed from the perspective of the WTRD.

An Innovation in Simulation, the first air-to air long-haul network technology demonstration

The Air Force Human Resources Laboratory, Operations Training Division, as the Division was known in the 70s, orchestrated the first technology demonstration of interactive long-haul networking of simulations on 14 Oct 79. In Mar 79, Col. Ron Terry, our Directorate Commander at the time, directed the division to connect two then state-of-the-art simulation systems. These systems were the Advanced Simulator for Pilot Training (ASPT) at then Williams AFB, located about 26 miles southeast of downtown Phoenix, and the Simulator for Air-to-Air Combat (SAAC) at Luke AFB, located about 20 miles west of downtown Phoenix. 382 bits of information per 30 hertz frame were used to transmit pertinent information between the two computers controlling the two simulators over four dedicated telephone lines. This work was largely accomplished by the late Mr. Chuck Snow, who was one of the many now largely unknown pioneers of simulation technology. This Oct 79 technical feat was documented in a Division produced videotape titled: "ASPT/SAAC Interface – An Innovation in Simulation".

In the 16 Mar 79 issue of the local newspaper, The Arizona Tribune, this demonstration is sited as identifying the Operations Training Division as being the birthplace of "cyberspace", having happened before science fiction author William Gibson introduced the term in his 1984 novel "Neuromancer". In a related observation, one of the Division's 90s researchers, Dr. Richard Thurman, who has now moved on to other things, often expressed his observation that the Division was performing "virtual reality" long before Jaron Lanier first coined the now widely accepted term.

## Early Simulator Networking Concept Evolution

The 80's concept of Simulator Networking (SIMNET) was actually born at the lab. Folks like

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then Capt. Jack Thorpe, then Lt. Mike Cyrus, and Dr. Elizabeth “Liz” Martin, all assigned to the lab in the late 70s, would sit around brainstorming what might be possible in the near and mid-term future for training systems technologies. The Arizona Republic newspaper article mentioned earlier named Liz Martin as the “Queen of Virtual Reality”, since she was the only female on the Division team working on the subject in that time. Mention this to Liz if you want to get a rise out of her. Thorpe’s 1976 mental contributions at the Division are documented in “Wired” magazine, out of The Hague, Netherlands, in their Apr 97 issue. What evolved in the 80s, after Jack Thorpe went on to be a Colonel at the Defense Advanced Research Projects Agency and Mike Cyrus left the AF and eventually established a company called Delta Graphics, was the first ever multi-player, long-haul networked, tank and armored personnel carrier training system for the US Army. The individual simulator systems at the time were updated at 15 hertz and had low display resolution, but this initial capability and its later upgrades grew to over 300 networked simulators that provided training for thousands of warfighters. The current Close Combat Tactical Trainer systems capabilities owe much to their SIMNET ancestors.

#### Direct Simulator-to-Simulator Network Connections

As the Division, and by then many other simulation facilities, progressed with multiship networked simulation, the best approach in most cases was a direct connection from simulator to simulator, what I’ll call a “hard-wired” network solution. In the hard-wired approach, every simulation essentially ran off of a single master clock with, in the case of the Division, shared memory and then reflective computer memory. My research for the writing of this paper could not identify a date or location of when this hardwired approach was first demonstrated using computer image generation for the visual scenes. But, the Division was among the first, if not the first, working primarily with fast mover military jet simulations. The Division used this hard-wired approach successfully for years over local area networks. Another early example of a high visibility successful implementation of this hard-wired approach was Kirtland AFB’s Special Operations Forces Network, or “SOFNET”. The Navy’s F-14 4-ship simulation system at NAS Oceana is yet another successful example. This hard-wired approach had its advantages. Things like close formation flying, weapons simulation fly-outs against moving targets, and aerial refueling (with a refueling tanker aircraft that has an interactive refueling boom that simultaneously pivots and extends) were, visually, nice and smooth and timely. The overall fidelity was limited by other parts of the simulation

system at the time, the image generators and display systems for example, and not by the hard-wired network. The disadvantage was that all participating simulation systems needed to be physically close to each other, essentially collocated, and there was no way to simultaneously train with offsite simulation systems.

#### The Air Force Association’s Air Force 50<sup>th</sup> Anniversary Technology Exhibition

In the 90s, during the period when the Division was a part of the then Armstrong Laboratory, our Division Commander, Col. Lynn Carroll, had a vision of what later became Distributed Mission Training (DMT) and is now referred to a Distributed Mission Operations (DMO). In anticipation of the Apr 97 Air Force Association’s 50<sup>th</sup> anniversary of the US Air Force Convention and Technology Exhibition in Las Vegas, Nevada, Col. Carroll decided to orchestrate a bold demonstration of his multiplayer networked distributed training simulation concept. Much of the simulation technical community at that time, and virtually all warfighter users, did not yet believe or were not aware that this capability was possible. This Air Force 50<sup>th</sup> technology demonstration would be a milestone for networked simulation technology and potential team training capability.

With most preparations starting as late as the Dec 96, the laboratory began integration of the numerous and various required pieces and parts. The Division would use all of our existing on-hand simulator cockpits; F-16Cs, A-10As, T-38As, and a C-130H3. Additionally, the then current versions of multiship control station / operations center featuring a large video wall, briefing and debriefing systems, electronic classroom, and night vision training systems would be used. Air and ground threats and friendly air constructive players would be supplied by the Division’s Automated Threat Engagement System threat and target server. Modular Semi-Automated Forces (MODSAF) would be configured to provide many other constructive players. We would also incorporate a networked Airborne Warning and Control System, or “AWACS”, weapons director simulation capability. There would be a “stealth” capability using a “virtual reality” prototype weapons director visualization trainer operating in the same scenarios with the non-stealth players. To demonstrate our recent advancements in visual display capabilities and to allow for display correlation across the four-ship of F-16 simulators, four identical rear projection full field-of-regard visual display systems were constructed. These numerous demonstration simulators and supporting systems, thought they would be positioned relatively

close to each other on the exhibit floor, would be networked together using the then quite new DIS protocol, which the Division had helped define and test.

The simulation industry was approached with the idea that, if they choose to participate in the celebration of the 50<sup>th</sup> anniversary of the US Air Force, they could also be in on the very beginnings of something that could revolutionize training. The Division was open to any and all vendors who wanted to contribute capabilities that would demonstrate the distributed training concept. The response was overwhelming. The Division actually had to turn folks away...

Lockheed Martin (LM) out of Orlando, Florida, volunteered to deliver their most impressive and beautiful (for the then available technology) demonstration database at the time, of the Elmendorf AFB, Alaska, area, in Simulation Interchange Format (SIF) to the Division. This Elmendorf AFB area database was an enhanced, marketing, version of their delivered Interoperable Visuals/Sensors for Air-to-Air Combat, or "IVAAC", database. LM knew and accepted that the SIF version of this database would be given to their competitors and would from that point on be government owned. LM also agreed to loan the laboratory two additional SE-2000 image generators, to give our four-ship of F-16C simulators identical image generators and simulator databases. LM also provided substantial technical expertise for integration support along with spare hardware parts.

Evans & Sutherland (E&S) provided two additional ESIG 4530 image generators, with spare hardware parts, and substantial technical expertise for integration support. These ESIG 4530s would drive our two A-10A simulators. E&S's version of an Alaska database would then run on these two loaner image generators in addition to running on our Division owned ESIG 4530 driving our C-130H3 simulator.

SGI wanted to participate in as big a way as possible to introduce their emerging capabilities, as they were just then actually breaking into the realtime image generation world. SGI, providing the graphics hardware, teamed with Wormald Technologies for the runtime software, and MultiGen, Inc. (now MultiGen-Paradigm) for the development of the database. The SGI solution drove two T-38A simulations, one of which was an early demonstration of the Division's Night Vision Training System team's night vision goggle simulation capability, and the prototype weapons director visualization trainer. SGI also provided hardware for a stealth station running MaK Technologies (who also provided

substantial people resources for system integration) software and supported a MODSAF simulation.

The kind contribution of the Alaska SIF database by LM provided a unique opportunity to have all demonstration players operating on the same geographic piece of simulated earth. Each of the participating database generation vendors had, on their marketing literature, recently begun to claim that they could read SIF data and output a runtime database in their specific vendor format. This was to be the first serious test of their SIF capabilities. There were some minor snags, but the SIF database was successfully converted by E&S and MultiGen in the very short period of time. MultiGen actually had to make two versions of the runtime database for this demonstration, due to specific runtime system requirements. The AFA 50<sup>th</sup> effort would not have happened as it did, with all players operating in the same geographic area using different runtime vendor databases, without the existence of the SIF standard.

The scenario for the Air Force 50<sup>th</sup> demonstration was specifically designed to optimize the demonstrations of individual image generator / simulator database capabilities, show off the most visually striking parts of the databases, and be as operationally realistic as possible. An imaginary crisis situation was written up as a standard intelligence briefing. The home airstrip (Elmendorf AFB), navigation turn points, and the objective area were defined as locations where the individual vendor databases needed to correlate as exactly as possible position-wise and color/texture-wise. It was understood and accepted that the individual simulator databases would "default" to their own database development system's terrain skin shape, cultural content and positioning, and moving model and special effects decisions in the remaining approximate 99% of the database. Within the Division defined scenario limits, as long as it didn't adversely effect the correlated exercise, the individual image generation vendors were encouraged to show off any particular capabilities that they thought highlighted their system above the others (one IG could have many more simultaneous 3D trees features than the others, etc.). This enforced definition of specific locations within the numerous databases to (just) meet the requirements of the defined exercise scenario was an early successful example of management of largely miscorrelated vendor simulator databases used in the same exercise event. The realistic mission scenario was scripted just enough to ensure the players ended up in the same gaming area at (about) the same time and were optimally visible to each other, and the exhibit audience watching on the video wall.

The deployment was impressive by simulation system standards. Fourteen semi-truck trailers and two moving van type trucks were required to transport 167 tons of equipment to the exhibit hall in Las Vegas. These numerous simulation systems were set up and tested by the Division's superb in-house contractor Hughes Training, Inc. staff along with representatives of the various participating volunteer outside vendors in a short four and a half days. This 18,000 square foot exhibit booth was successfully set up in what turned out to be a hostile environment, with an excessively overheated exhibit hall during set-up and counterproductive labor union interference.

For the three public exhibit days, 22 – 24 Apr, combat ready operational Air Force aircrew warfighters, used to add validity to this still novel distributed training concept, flew 17 mission exercises in front of a large and interested audience. A large banner above our booth stated "Revolutionizing Training" and accurately defined our belief in the future of this distributed networked training capability. Exhibit attendees included Air Force veterans and high visibility heroes from before and after World War II, along with the current Air Force movers and shakers of the 1997 timeframe. All had a varying understanding of interactive simulator networking as a potential training capability. Interestingly, almost all mission exercise spectators were very slow to understand, or even "believe", that the various simulation systems on the exhibit floor were "really" networked together in the same exercise. Eventually, "most" spectators would come to understand that the simulators really were interacting with each other in the same mission exercise and, importantly, that different things could end up happening on each mission. Another curiosity was that several spectators asked if these simulators were "deployable". We gently reminded them that, as these numerous networked simulators were being demonstrated on an exhibit floor far from their Arizona home Division facility, they actually "were" deployed. Our definition of "deployable" in this case was 'not' referring combat theater type quick transport, setup, operation, and teardown ruggedization. Instead, the deployable reference was to the fact that very large amounts of such fragile simulation system components could be set up far away from and outside of their traditional sterile air conditioned and surge protected home simulator high bays.

This technology demonstration was attended by the then USAF Air Combat Command (ACC) Commander, General Richard Hawley, the then Chief of Staff of the USAF, General Ronald Fogelman, and about 100 other international AF Chiefs of Staff. General Hawley told Col. Carroll that "we" (the

Division) were just about "there" for what he envisioned as truly adequate for ACC training. The available technology of the image generation systems and the out-the-window display resolution were specifically identified, by General Hawley, as the remaining deficiencies.

The Air Force 50<sup>th</sup> technology demonstration successfully demonstrated the first ever multiship distributed training capability with numerous and different weapon system types (F-16Cs, A-10As, T-38As, and a C-130H3), support functions (AWACS, stealth, mission control, etc.), with different vendor image generator types running largely miscorrelated simulator databases, using a long-haul network protocol. This was a successful example of government and numerous contractor organizations (many not even mentioned in this paper) coming together quickly to demonstrate a very challenging, never before accomplished capability. The Division's rear projection out-the-window visual display system known (mostly) as the Modular Mini Display for Advanced Research and Training, or "M2DART", or sometimes just "DART", was first demonstrated to a large audience and in this four-ship F-16C configuration. This demonstration led directly to the numerous DART spin-offs, becoming the display system technology of choice for single seat fighter-type simulation. This was the first large audience demonstration of the 10 channel DART system supporting a side-by-side seat cargo aircraft simulation, the C-130H3 in this case. The Air Force 50<sup>th</sup> was also a successful example of management of a large-scale exercise scenario using numerous dissimilar image generator equipment types and, remarkably, largely miscorrelated vendor simulator databases. These Alaska simulator databases are, to date, still the only common geographic area that is government owned data in LM, E&S, and OpenFlight formats, and in SIF. These resulting Alaska databases were delivered to the DoD Standard Database Facility at Kirtland AFB for future government use. This Air Force 50<sup>th</sup> development effort is documented in several Division produced videotapes and documents along with numerous participating vendor documents. The Division received Aviation Week and Space Technology's 1998 Technology Innovation Award and the 1999 Red River Valley Fighter Pilot's Association Award for the Air Force 50<sup>th</sup> technology demonstration.

After the Air Force 50<sup>th</sup>

The E&S and SGI / Wormald / MPI teams included some very limited photospecific texture capability in their simulator databases for the AF 50<sup>th</sup> effort. This capability, at the time, looked promising for use over large geographic area databases for

single-ship and networked simulations. E&S, SGI, and many others then continued development of this capability. Working closely with the Division, SGI expanded upon an evolving internal high pixel resolution runtime software capability that lead to a demonstration of large area, high texel resolution, full color, photospecific Madrid, Spain, area simulator database demonstrated by the Division at the Nov 98 Interservice / Industry Training Systems and Education Conference, or "I/ITSEC". This capability came together so quickly that there was no time to arrange for a proper exhibit booth. The capability was set up in a "Suite" and demonstrated for one day only. You just had to be there... General Hawley, upon hearing about this capability, came directly to the Suite from delivering the I/ITSEC Keynote speech, bypassing the Exhibit Hall. After flying the system, General Hawley announced to Col. Carroll that, although the display resolution still needed improvement, we were "there". That, the General proclaimed, was exactly what he wanted for ACC for training systems as soon as possible. The General also made the comment, while pointing to the simulation system: "'This'... is 'my' new standard...". These two demonstrations, the Air Force Association 50<sup>th</sup> Anniversary Technology Demonstration and the 1998 I/ITSEC, lead directly to General Hawley's declaration that the Air Force acquisition system should deliver "that" specific capability, and fast, to ACC. That acquisition is a very interesting story in itself that is for Wright-Patterson acquisition representatives to tell.

After I/ITSEC 98, the Division pursued image generation technologies that were both lower cost and photospecific capable. SGI first demonstrated a high-end (large geographic area, far visibility, totally photospecific, natural color, multi-channel, solid 60 hertz non-interlaced, anti-aliased, with well over a million pixels per channel per frame) image generation system at a low dollar cost. What just a few years earlier had cost a million dollars per channel for a "cartoon looking" capability soon cost an incredibly low \$150K or so per channel for an incredibly improved photospecific capability that was enthusiastically received by the operational warfighter aircrew. For the first time, aircrew actually "wanted" to fly the simulators. The networking of high end fast mover military jet continues to become more affordable and attractive to warfighter users.

The Division has also followed the progress of personal computer, or "PC", systems capabilities for realtime image generation. PC image generation, having been described since about 1997 as being six months to two years away from catching up with the "traditional" image generation system capabilities, is only now truly attaining (essentially) this capability.

PC image generation capabilities will increasingly benefit networked simulation at all levels of fidelity. This paper will not go into details about PC image generation use since this subject is covered by countless other publications.

## DIS Demonstrations and Exercises

The lack of network protocol standards was a serious problem for the pioneers of long-haul networked simulation. As stated earlier, the Division participated in the early development and test of the Distributed Interactive Simulation (DIS) protocol. Both before and after the Air Force 50<sup>th</sup> technology demonstration, several DIS capabilities were rigorously proven out on Division simulation systems. Examples where the Division played a substantial role are Roadrunner 98, Air Force Association 1999 and 2000 Convention technology expositions, Fighter Fatigue study, Coyote demonstration(s), Desert Pivot Exercise(s), Combat Identification exercise, Virtego demonstration, Cyclone demonstration, Situational Awareness Study, Warbreaker demonstration, Joint Combat Search and Rescue exercise, Joint Strike Fighter "VSWE" exercise(s), Multi-Distributed Training Testbed exercise, Joint Expeditionary Forces Exercise(s), Fighter Fatigue study, Fighter Lead-In Training, Flight Lead Upgrade Training, Weapons Instructor Course training, several I/ITSEC exercises such as Desert Rat, Coalition Mission Training Research demonstration(s), and many others. Division personnel, now the Air Force Research Laboratory Warfighter Training Research Division, continue to participate in the networking standards refinement process and to explore enhancements and expanding demonstrations of DIS capabilities.

## An Example Current Effort, Fighter Weapons Instructor Course Training

F-16 Fighter Lead-In Training and Flight Lead Upgrade training research has been conducted by the Division's Dr. Peter Crane and coordinated by Mr. Jeff Carr. Operational F-16 aircrew and air or ground based weapons controllers (controlling the F-16s) experience a week of four versus many simulator engagements. The F-16 aircrew experience training in being the four-ship Flight Lead, including leading the prebrief, mission execution, and the debrief. Missions become, generally, progressively more challenging over the week. Missions include various air and ground threats and levels of weapons controller "control". A new and refreshing phenomenon is that the visiting aircrews "like" flying Division simulators for this type of training. Comments like: "This is the best air-to-air training

I've ever had." and "I've got more air-to-air training in a week than I can get in a year back home." are common. Aircrews regularly get out of the simulators and "high-five" each other. The weapons controllers have the advantage over real life operations in that they can debrief the missions in the same room as the fighter pilots they were controlling. The weapons controllers feel this is a tremendous benefit to their future mission effectiveness. Debriefings can take longer than they would after a real mission, due to the fact that aircrew can get into operational details that very rarely come up in the real world due to airspace, switchology, and number of available aircraft limitations. Aircrew have been known to be a hour and a half "late" to previously announced free beer and food due to their staying late in the debriefings because they were, in their words, "having fun" getting into mission details they can't get into after a real life mission. An example of how the aircrew "gets into" the simulation is that more than once Dr. Crane has recorded anti-G strain breathing noises while the aircrew were in the thick of simulated battle, even though there are no G forces in the simulators. At the end of each week of training, aircrew regularly inquire about how soon they can come back and ask if they can bring their whole squadron next time. This is highly motivating to hear for simulator folks. Often, F-16 aircrew would purposely schedule a week at the Division immediately before going on to attend the Fighter Weapons Instructor Course (WIC), just to hone their skills. Feedback about the advantages of visiting the Division before attending the WIC led to the Division's networked simulators being an actual "part" of WIC training. The high degree of aircrew acceptance in our current fidelity F-16 and weapons controller simulator systems and the brief and debrief systems is a positive indicator for the future of networked simulation DMO.

#### Quick Mention of the Simulator Database Correlation Issue

It should be mentioned that, just because you can successfully short or long-haul network, that doesn't at all mean your individual participating simulator databases terrain skin shapes, level of detail schemes, texture types, colors, inter-visibility schemes, numbers and types 2D and 3D cultural content and locations, and numbers and types of simultaneous moving models and special effects, and earth coordinate definitions will "correlate". Simulator database (mis)correlation is a serious and often underappreciated factor that needs to be properly 'managed'. But, that's another complicated story...

#### The High Level Architecture Phenomenon

At about this point in our story the High Level Architecture (HLA) was born. As the role of simulation in the training of operational warfighters rapidly expanded, DoD looked around and saw two rapidly diverging communities forming. The constructive simulation camp, which was primarily concerned with theater-scale exercises involving thousands of entities modeled at a low level of fidelity, was relying on the Aggregate Level Simulation Protocol (ALSP) to connect their simulations. ALSP was the protocol of choice for exercises such as Blue Flag and Ulchi Focus Lens, where updates rates on the order of once a minute were more than adequate. The virtual simulation camp on the other hand relied almost exclusively on DIS to provide multiple updates per second on their relatively small number of very high fidelity entities. Attempts to combine the two were only moderately successful, as entities modeled in ALSP systems seemed to jump all over the sky in the visuals of a 60 Hz cockpit simulator. Integrating the two systems also required the expensive development of additional interfaces for existing models, which in practice usually meant adding a DIS interface to ALSP systems.

HLA arose as a well-intentioned effort to bring these two camps together. The DoD Modeling and Simulation Master Plan had mandated the development of a common architecture for simulation interoperability. HLA was designated as this architecture in the now-famous Kaminski memo of September 1996. In this memo the Undersecretary of Defense for Acquisition and Technology, Dr. Paul Kaminski, laid out two important dates for the now-mandatory transition to HLA: "The Department shall cease further development or modification of all simulations which have not achieved, or are in the process of achieving, HLA-compliance by the first day of FY 1999, and shall retire any non-compliant simulations by the first day of FY 2001." These dates became known respectively as the "No Can Pay" and "No Can Play" dates. While a waiver process was provided, funding for HLA development, for the most part, was not. As of February 2003 36% of Air Force simulations were HLA-compliant, 45% had been granted extensions, and 11% were stand-alone systems with no networking capability. The remaining systems were either being retired or had received various other waivers.

HLA also aimed to overcome a significant limitation of the DIS protocol: bandwidth consumption. DIS transmits Protocol Data Units (PDUs) between simulators via Uniform Data Protocol (UDP) or "broadcast" transfers. As the number of entities in a

simulated environment grew, the amount of data being broadcast around the network grew as well. As scenarios became more complicated, networks quickly became saturated. HLA was designed to overcome this limitation by passing data more selectively. We'll discuss this and other features of HLA later.

### HLA Redux

Before we can talk about the differences between HLA and DIS we need to give a little more detailed description of DIS. DIS is now formally defined by IEEE Specification 1278, which anyone can refer to for more details. In simple terms, the DIS standard defines everything necessary to interconnect simulation systems. Coordinate systems, algorithms for modeling the movement of entities, and the formats of the various messages that have to be exchanged are all laid out in detail.

Now let's compare this to HLA (IEEE Specification 1516 for those who want more detail). One of the first things you'll notice is that there is no "P" in HLA. ALSP is the Aggregate Level Simulation *Protocol* and DIS is really the Distributed Interactive Simulation *Protocol*. HLA, on the other hand, is the High Level *Architecture*. While this sounds like the beginnings of a very esoteric discussion on semantics that is best left to lawyers, it actually has very practical implications for simulation developers, managers, and users.

In order to fully explain this, you first need to understand the concept of SOMs and FOMs. A SOM is a system's Simulation Object Model. It represents all the objects, attributes, and interactions that the system *can* share externally. Each simulator in an HLA federation brings its own SOM to the table, and the federation managers then develop the FOM. The FOM, or Federation Object Model, represents all the objects, attributes, and interactions that *will* be shared by that particular federation. Both the FOM and the SOM are represented in the Object Model Template (OMT), which is a table-based standard for representing the data.

HLA also provides what is known as the Runtime Infrastructure (RTI). The RTI is the "traffic cop" that manages all communication between the federates. As opposed to DIS, in which simulations broadcast their information across the network and receiving simulations either process it or discard it, HLA requires systems to "publish" information to the RTI, which then passes it only to those systems which have "subscribed" to that information.

Finally, HLA provides a set of ten rules, five for federates (individual simulators) and five for federations. These rules govern the behavior of HLA systems by stipulating, for example, that all federations shall have a FOM, all FOM data shall be exchanged via the RTI, all simulators must have a SOM, and all simulators must abide by the provisions of their SOM.

And that's it. Nowhere does HLA specify the format of data to be exchanged, coordinate systems to be used, or any other detailed information. That's left to the federation managers to determine when they bring all of their SOMs together to settle on the FOM. This led to the unhappy realization on the part of many simulation program managers that HLA-compliance did not guarantee interoperability. Two systems could both be HLA compliant but be utterly unable to interoperate if, for example, they employed different coordinate systems, or different attribute definitions for similar objects. These differences had to be addressed during the FOM development process, which in the early days of HLA this was unhappily labeled the "FOM-o-rama" because it often involved a lot of horse-trading between the federation managers. Interoperability can only be achieved *after* a FOM has been agreed upon by the simulators participating in a federation and any necessary software modifications have been made to bring the systems into compliance with the FOM. Many uncomfortable moments have been spent briefing bosses on the development effort required to participate in a particular federation *after* DMSO has certified a system HLA-compliant.

### AFRL/HEA Dives Into the HLA Pool: Tasmanian Devil

Following the success of the Roadrunner 98 DIS based exercise, the division hoped to repeat its good fortune with efforts named after Warner Brother's cartoon characters. The Tasmanian Devil Project, also known as Taz, was a cooperative effort between DMSO, AFRL/HEA, and the U.S. Navy Air Combat Environment Test and Evaluation Facility (ACETEF) Aircraft Simulation – Manned Flight Simulator (MFS) Facility. The purpose of the project, which began in May 1998, was to gain experience in the application of the HLA to the DMT domain. The goal of Tasmanian Devil was to develop and demonstrate two federations that utilized different aircraft training simulators but a common FOM to execute a common 2vX air-to-air training scenario. The federations were designated TAZ-AF and TAZ-Nav for the Air Force and Navy efforts respectively. The participants hoped to gain experience in following the Federation Execution and



Development Process (FEDEP) and to share lessons learned with the real-time simulation community.

Taz was originally envisioned as a single effort to execute the FEDEP and produce a federation suitable for the DMT community. The participants approached the effort as if they were developing a real-world federation, not a research prototype, so that they would understand and execute the process the wider simulation community would eventually have to follow and thereby provide more pertinent lessons learned. Right away, a very important lesson was learned when the first FEDEP steps, which had been scheduled to take a few weeks, turned into the dreaded “FOM-o-rama” and took almost two months to complete. Given the project’s seven-month timeline, this meant that development was not yet complete at the scheduled end of the project. While both federations were operational, they were neither robust nor stable enough to truly be deemed useable for training. A second phase of the project was consequently undertaken to enhance federation functionality and stability, and to undertake some initial federation performance measurements.

By the end of Phase II, it was generally agreed that the use of HLA had been successfully demonstrated in a high fidelity air-to-air training environment. At the same time, it was also agreed that Taz had not produced an equivalent level of fidelity as had been capable under DIS, and that HLA was less efficient from a software development standpoint, requiring significantly greater amounts of memory than DIS. In fairness to HLA, Taz was a beta-test of DMSO’s latest RTI technology, and was the first-ever use of the VxWorks real-time operating system version of the RTI. Several performance issues that were noticed during Taz were later proved to be the result of compiler issues with this new version of the software. Currently, AFRL/HEA is investigating commercial RTI software developed by MaK Technologies, and the results look promising.

#### Reference FOM’s: The Cure for the Common FOM-O-Rama?

As the DIS community came to realize that HLA was not going to go away, they began to look pragmatically at ways to bring their experience to bear and improve it. What they came up with was the Real-time Platform Reference (RPR), pronounced like “reaper”, FOM. The goal of the RPR FOM was to define the objects and interactions that were provided by the DIS standard in the HLA vernacular. As Paul Gustavson described it, the RPR FOM “tasted like DIS but worked like HLA.”

Together with the accompanying Guidance, Rationale, and Interoperability Modalities (GRIM – get it?) the RPR FOM was designed to be a dictionary of sorts, defining all of the objects and interactions that were available under DIS. Simulation developers could chose the objects and interactions required by their system, develop their system to communicate this information via the RPR FOM format, and have a system that should be compliant with other RPR FOM simulators.

Today the RPR FOM offers arguably the best native-HLA hope of overcoming the lack of interoperability that has plagued HLA. While other efforts, such as the development of Base Object Models (BOMs) are under development, federation managers are building FOM’s based on the RPR FOM *today*. Efforts such as the NATO First Wave Exercise and the Air Force Distributed Mission Operations (DMO) FOM are based on the RPR FOM. The US Navy is actively developing the Naval Training Meta-FOM, which is also based on the RPR FOM.

There is another option on the horizon, at least in the Air Force DMO community, which bears watching. As the Operations and Integration contractor for the Air Force DMO network, Northrop Grumman (formerly TRW) faced the challenge of interfacing Mission Training Centers across the country that shared no common communication protocol. Their solution, which is still under development, is the DMO portal. The portal will act as a gateway translating data exchanges between sites. This should allow relatively seamless communication between sites utilizing HLA and DIS. What remains to be seen is whether these translations can truly be accomplished without data loss, as well as the impact on latency that this additional software layer will have.

#### DIS or HLA?

The \$64,000.00 question remains which protocol should I use? While we can’t answer that one for you, we can offer some insights. To begin with, if you’re a military organization the HLA mandate has not gone away. Each of the services has signed a memorandum of agreement with DMSO that reaffirms their support for the HLA transition and requires their systems to become HLA compliant. As more and more real-time systems gravitate toward FOMs derived from the RPR FOM, HLA interoperability will become easier and easier to achieve. DMSO has ceased providing free RTI software, which has opened up the market to commercial vendors whose products will only get better. So if you’re in it for the long haul, HLA compliancy is a smart investment and the earlier in

the development process the decision is made the better.

With that said, and much to DMSO's chagrin, HLA compliancy does not necessarily mean HLA operations. While AFRL/HEA's cockpit simulators are all HLA-certified, we have retained our ability to run DIS, and quite frequently do. As a more established software base, it is often times more stable than an HLA implementation, and meets the requirements for small-scale scenarios. We recently conducted networked simulator training involving USAF pilots in Mesa, AZ and RAF pilots in Bedford, England using DIS and ISDN lines.

DIS is also an excellent choice for projects where fast integration is the driving factor. Avoiding the FOM development stage and allowing each system to undertake development independently, so long as they adhere to the PDU standards, can often achieve interoperability faster. This is especially true for internal projects where the simulators are co-located and can communicate over a LAN, alleviating concerns about bandwidth consumption on expensive, long haul lines.

### Conclusion

The WTRD has been in the thick of realtime networked simulation since the early days. The Division therefore has a unique and far ranging perspective on this technology. Many past and current network simulation capabilities were conceived, developed, demonstrated, enhanced, and / or tested at or by the Division. There is certainly more "to" the network simulation story as viewed from the perspective of other simulation organizations. This paper documents experiences and recommendations about the many aspects of realtime networked simulation from only the WTRD perspective. The Division continues to contribute to advancements in networked simulation technology.

### Authors

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